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# Observations on the Movements of Atlantic Salmon (*Salmo salar* L.) in the River Conon and the River Meig, Ross-shire. I.

By K. A. PYEFINCH and D. H. MILLS, Ph.D.

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By K. A. PYEFINCH and D. H. MILLS, Ph.D.
*Freshwater Fisheries Laboratory, Pitlochry*

EDINBURGH: HER MAJESTY'S STATIONERY OFFICE
1963

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## EXPLANATORY NOTE

This report discusses the records obtained during the first four seasons of the operation of a scheme of research on Atlantic salmon which has become known as the Conon Salmon Research Scheme. This scheme was proposed by the North of Scotland Hydro-Electric Board and it has been financed by a grant from the Development Commission. The research has been supervised by a Committee, under the Chairmanship of Professor Sir James Gray, C.B.E., M.C., Sc.D., F.R.S., which includes representatives of the Conon District Fishery Board, the Ministry of Agriculture, Fisheries and Food, the North of Scotland Hydro-Electric Board and the Department of Agriculture and Fisheries for Scotland. In the original plans for this scheme, the Hydro-Electric Board agreed to appoint the scientist in charge and the Scottish Home Department (whose functions relating to fisheries are now discharged by the Department of Agriculture and Fisheries for Scotland) undertook to provide a junior scientist, who would act as his assistant. The Hydro-Electric Board appointed the late Dr. V. D. van Someren as scientist in charge. He took up his duties with the Board during the autumn of 1955 and remained in charge of the Conon Scheme until he resigned his post with the Board in April 1957. Dr. van Someren was therefore responsible for all the initial planning of the field work connected with this scheme and this is a suitable opportunity to pay tribute to Dr. van Someren's work over this period. Often working under difficult circumstances, he devised a number of temporary traps which enabled some records to be obtained during 1956 and he was largely responsible for the design and installation of the permanent traps below the Meig and Luichart dams, which were completed just before he left.

When Dr. van Someren left, the Scottish Home Department agreed to second a member of their freshwater staff to take charge of this project. Mr. K. H. Balmain, who was asked to undertake this task, took up his duties in April, 1957 and remained until the following October, assisted by Mr. D. H. Mills who had been appointed as the junior scientist for the scheme in March, 1957. When Mr. Balmain left, Mr. Mills was placed in immediate charge of the project and has continued in this capacity throughout the rest of the period covered by this report, for which he and Mr. K. A. Pyefinch (the Officer-in-Charge of salmon and freshwater fisheries research) are responsible. The census is continuing and it is proposed to publish further results in later reports.

# Observations on the Movements of Atlantic Salmon (*Salmo salar* L.) in the River Conon and the River Meig, Ross-shire. I.

## INTRODUCTION

This paper describes observations on salmon migration made, over the period 1957 to 1960 inclusive, on two tributaries of the River Conon, Ross-shire. Both these tributaries, the Meig and the Bran or Conon,* have been used for hydro-electric developments and traps to take all ascending and descending migrants were erected a short distance below the dam on the River Meig and the dam at the lower end of Loch Luichart.

The Meig is one of the important spawning tributaries of the Conon system but the Bran does not carry a natural population of salmon as the Conon falls, situated a mile above the confluence of the Conon and the Meig, were impassable to salmon. These falls have now been modified so that upstream migrants can pass beyond them but, for nearly all the period covered by the observations recorded in this paper, these migrants have not been allowed to pass beyond the trap below Luichart dam.

By means of the arrangements mentioned in the previous paragraph, the experiment was intended to compare smolt production from natural spawning in the Meig with that from artificial planting in the Bran. This comparison was an important element in the plans for this investigation because, although information is available on the relative efficiency of natural and artificial propagation on some species of Pacific salmon (e.g. sockeye (*Oncorhynchus nerka*) Foerster, 1929a, 1929b, 1929c, 1934) there is little direct information on this subject for Atlantic salmon. Unfortunately, for reasons given later, it was not possible to make a strict comparison, but the estimate made of smolt production from the two systems is as accurate as possible. This census has, however, provided information on the movements of salmon in rivers where there are hydro-electric developments.

## SITE

A general description of the Conon River system has been given by Menzies (1928). Hydro-electric developments on this system began in 1949 and the present state of the part of this river system with which this paper is concerned is shown in Fig. 1. The lowermost dam, completed in December 1954, is at Torr Achilty. This dam is 50 ft high and the reservoir above it, Loch Achonachie, collects water from the Conon, the Meig, the Bran, the upper waters of the Orrin and the Blackwater and Loch Fannich. There is a Borland fish lift in the dam, which allows the upstream passage of adults and the downstream passage of kelts. Some of the smolts may migrate downstream by means of this lift but most of the smolts probably pass through the turbines of the power station built into the dam. There are two Kaplan turbines, which work under a head of 50 ft.

Meig dam, 52 ft high, was completed in September 1956 and most of the water impounded by this dam is carried into Loch Luichart by means of a tunnel, some 1½ miles long. There is a Borland fish lift at Meig dam and this is the sole provision for passage upstream or downstream for migrants of all ages (except during periods of spill), as the entrance to the Meig-Luichart tunnel is screened to prevent the entry of smolts. These screens have a mesh, one inch horizontal and one half inch vertical, which is widely used in hydro-electric installations in Scotland. By agreement with the Conon District Fishery Board, a compensation flow of 37 cusecs is maintained down the River Meig from the impoundment above the dam during the period 15th March to 16th October which is reduced to a flow of 9 cusecs over the remainder of the year.

Luichart dam, 62 ft high, was constructed across the lower end of Loch Luichart, a natural loch which was increased in area following the closure of the dam (in July 1954) and the diversion of water

* It should be noted that the stream entering Loch Luichart is called the Bran, whereas the stream running out of this loch is called the Conon.

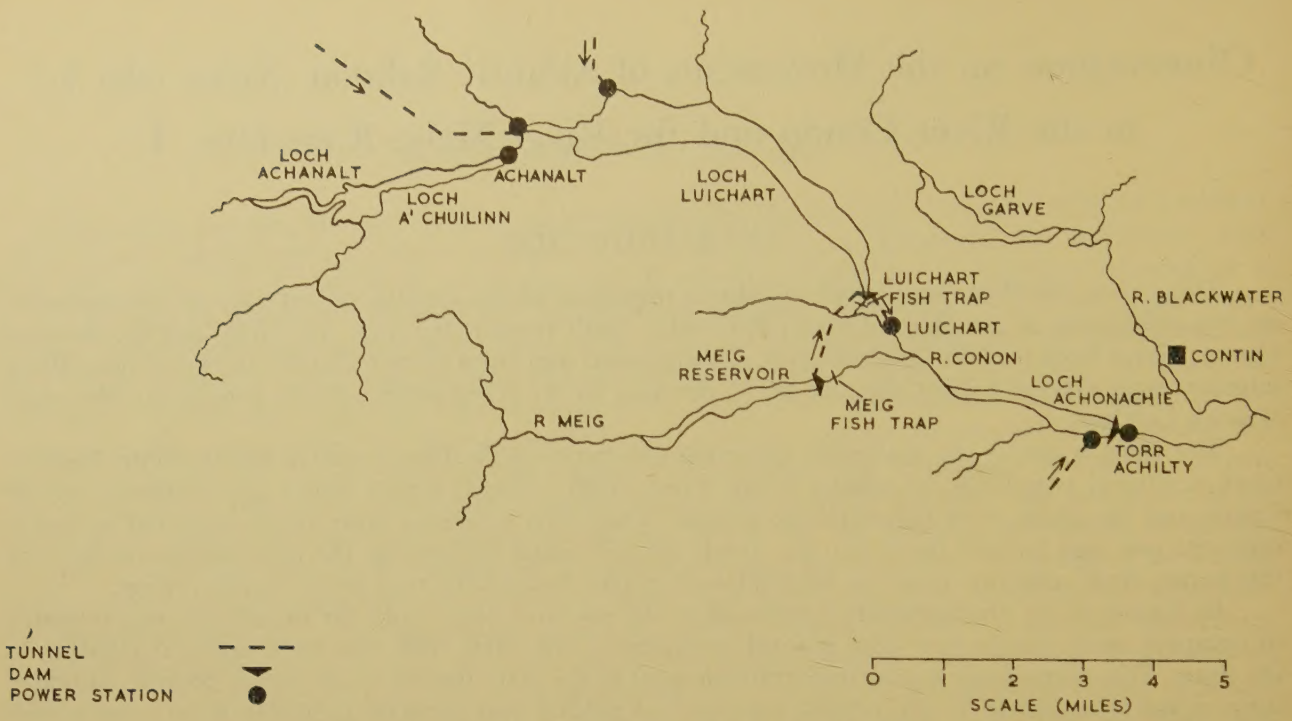


Fig. 1. Sketch map of the Conon Hydro-electric Scheme.

into the loch from the Meig impoundment and elsewhere. There is a Borland fish lift in the dam which was installed to facilitate the downstream movement of parr and smolts. The arrangements for compensation water are the same as those at Meig dam. Water from Loch Luichart is led, by means of a tunnel, to Luichart power station, situated about a mile below the dam, where there are two Francis turbines, working with a gross head of 185 ft. The tunnel leading to the power station is fitted with smolt screens at the point where it leaves the loch.

Finally, mention should be made of the arrangements at the lower end of Loch a'Chuilinn, a small loch which lies on the Bran about one-and-a-half miles above Loch Luichart (Fig. 1). Here a barrage was built across the river, incorporating a short Borland fish lift for the passage of migrants. This barrage stores water for short periods for Achanalt power station, situated about half a mile downstream. There is a Kaplan turbine in this power station, with a gross head of 65 ft and juvenile downstream migrants are allowed to pass through this turbine. A pool-type fish pass, has also been installed at the falls adjoining the power station to allow the passage of adult fish upstream and smolts and kelts downstream, though upstream migrants only began to use this pass towards the end of the period covered in this paper as adults were not allowed to pass into Loch Luichart until August 1960.

## METHODS

### (*a*) Traps

The census described in this report was carried out at the two traps below Meig and Luichart dams. These two traps were constructed during the spring of 1957, but some trapping facilities were available for periods during 1956. Below Luichart dam a simple box trap for downstream migrants was in operation during March and April 1956, and this was then replaced by a grid-type trap which remained in operation until late October. A temporary box-type trap, designed to catch ascending adults, was erected below Meig dam and was in operation from 23rd June to 30th July 1956, when it was swept away during a spate.

The two traps built in 1957 had the same basic design. Each consisted of a grid trap for descending fish and a series of holding pools for ascending fish. A plan of the Meig trap is shown in Fig. 2.

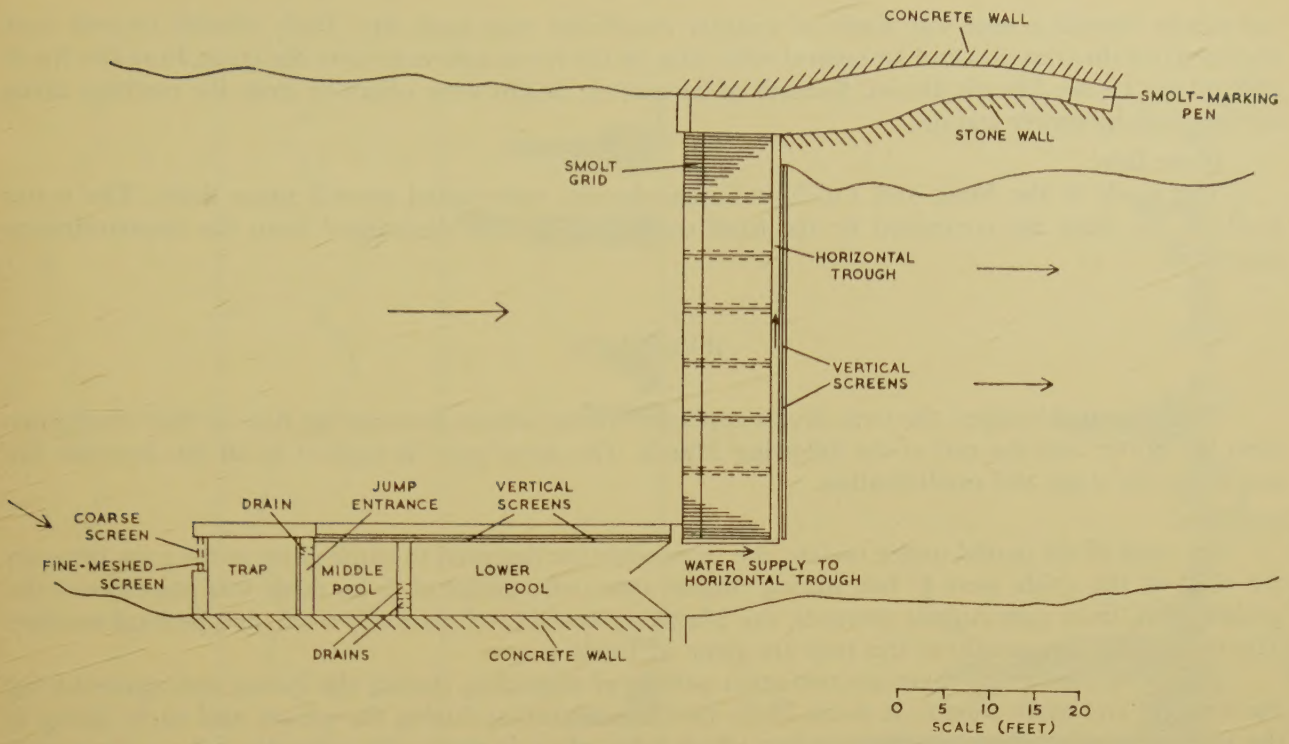


Fig. 2. Plan of the Meig trap.

The Meig trap came into operation on 1st April and the Luichart trap on 17th April 1957 and both have since worked very successfully. Except for short periods, when spills from the dams upstream put them out of action, they have fished continuously during the period under review. A number of minor modifications have been made in the light of experience gained during operation and they can now withstand spates of up to 3,500 cusecs without sustaining structural damage.

(*b*) Observations on Fish

During the period April to November each year a 24-hour watch has been maintained on each trap, with one trap watcher on duty at any one time. During the period November to April, watch has been kept by pairs of trap watchers, who were on duty during the hours of daylight only. The traps were fished as often as conditions required; they were emptied several times a day when a major run was in progress.

A proportion of the smolts captured at each trap was measured and samples of scales taken. It was agreed with the Conon District Fishery Board that the proportion of smolts tagged at Meig should not exceed 30% of the run, but the proportion tagged at Luichart was sometimes greater (see Table 7).

No ascending adults or descending kelts were tagged. During 1957 approximately half the ascending fish at Meig were weighed and the weight of the remainder estimated, whereas at Luichart 80% of the ascending fish were weighed, measured and scaled and estimates made of the weight of the remainder. All ascending fish were measured at Luichart and Meig from 1958 onwards.

(*c*) Observations on Environmental Factors

*Temperature*

Air and water temperatures were taken hourly throughout the period of trap operations by means of a Six's maximum and minimum thermometer.

*Weather Records*

From April to November each year weather conditions were recorded three times a day but during

the winter months a note was made of weather conditions once each day. Daily rainfall records were obtained, for the trap sites and for several other sites on the rivers upstream from the traps, from the North of Scotland Hydro-Electric Board. Records of barometric height were obtained from the readings taken at Torr Achilty power station.

*Water Level*

The levels in the Meig and Luichart impoundments were noted several times daily. The water levels at the traps are controlled by the fixed compensation flow discharged from the impoundments upstream.

## RESULTS

Throughout this paper, the term 'fry' is applied to young salmon between the date of their emergence from the gravel and the end of the following March. The term 'parr' is applied to all fish between the end of the fry stage and smoltification.

### (*a*) Parr

For most of the period under review, the traps were not designed to catch parr, as the gaps between the slats of the grids were $\frac{3}{8}''$ but, during August 1960, wire gauge of $\frac{1}{10}$ in. mesh was placed over the grids so that, from 19th August onwards, the Meig trap could catch parr of 7·0 cm. and perhaps smaller. The number of parr caught at this trap are given in Table 1.

This table shows that there are two main periods of migration, during the spring and again during the autumn and early winter. It seems likely that the migration during the winter and early spring is the forerunner of the true smolt migration which takes place in succeeding months and, as the season advances, it becomes increasingly difficult to classify some migrants as either parr or smolts. It is not known whether the downstream movement during the autumn culminates in a migration into salt water but it is doubtful whether this movement is a true migration to sea. Evidence from the Tay estuary (Calderwood, 1906) indicated that there the number of parr caught increased in November and that some were becoming silvery which suggested that they were perhaps migrating to sea but more recently Europiezewa (1957) found that the number of parr in a creek increased during September and October, but that the parr caught later in the season showed no signs of silvering, though some silver parr had been present during the summer. Saunders (1960) has reviewed the observations on autumnal movements of parr.

It will be noticed in Table 1 that the number of parr entering the trap during December 1959 and February 1960 was much larger than in corresponding months in other years. This abnormal movement seems likely to be connected with the release of water from the impoundment upstream which was being de-watered to enable modifications to be made at the dam.

Measurements were made of the length of the parr caught at the Meig trap but they are not quoted in detail here because, owing to the design of the trap for most of the period reviewed, they cannot be regarded as a representative sample.

A few parr were also taken in the Luichart trap, but the numbers were too small to allow any conclusions to be drawn about their seasonal occurrence.

### (*b*) Smolts

Details of the number of smolts caught at the Meig trap are given in Table 2 which shows the weekly totals over the period April to September for the four years under review.

This table shows that there has been a main period of migration each year, together with shorter periods in which smolts have migrated in smaller numbers. In 1957 the main migration took place during the last week in May and the first two weeks in June, in 1958 it occurred during the middle three weeks of May, in 1959 it was distributed fairly evenly through the month of May and in 1960 most of the run took place during the second half of May. Smaller runs usually took place in April and in June each year.

A number of attempts have been made to correlate the onset of the main migration of smolts with various environmental factors, chiefly rainfall (Bull, 1931, a, b) water temperature (Berry, 1932, 1933;

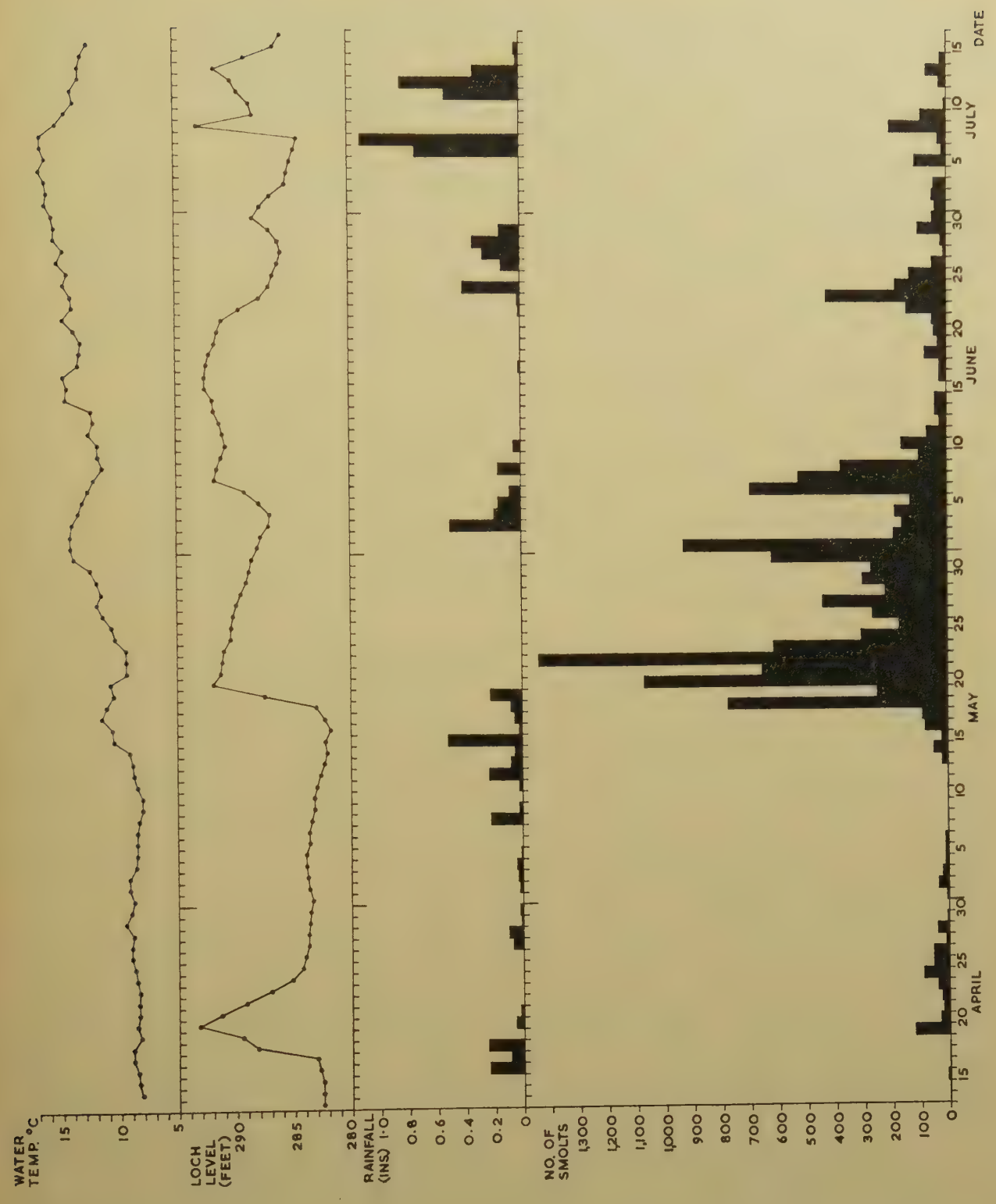


Fig. 3. Smolt migration through the Meig trap, 1957.

White, 1940; Allen, 1944 and Europiezewa, 1957) and water level (Berry, 1932, 1933; White and Huntsman, 1938 and Allen, 1944). An examination of the variation of a number of environmental factors over the main period of smolt migration through the Meig trap suggests that an increase in the number of fish migrating is most often associated with an increase in water level in the impoundment upstream which, in its turn, is associated with rainfall. Fig. 3, which shows the variations in loch level, water temperature, rainfall and daily catches of smolts over the period April to July 1957 is given as a typical example of the result of this kind of analysis.

Table 2 also shows that the size of the smolt run through the Meig trap has, in general, apparently decreased over the four years under review and that the run in 1960 was only about half that in 1957. Unfortunately, it is not certain that all these counts are complete and it is therefore necessary to try to evaluate each year's records separately. As will be seen from the succeeding paragraphs, most of the complications have been produced because there is evidence that, at various times, smolts from the Meig system have been able to pass into Loch Luichart through the Meig-Luichart tunnel.

In 1957, no attempt was made to assess the magnitude of any losses to the Luichart system but, because there was little flow through the tunnel during the period of the smolt run that year (for two-thirds of this period the gate at the entrance to the tunnel was closed), the loss may have been slight and the run recorded (about 14,000 smolts) reasonably complete.

In 1958, a batch of 999 hatchery-reared smolts, tagged before release, was liberated in the Meig impoundment. Of these, 174 were recaptured in the Meig trap and 19 were recaptured in Loch Luichart or in the Luichart trap. The recaptures of these tagged fish therefore suggest that the proportion passing through the Meig-Luichart tunnel to those passing down the River Meig to the trap was about 1:9. The hatchery-reared smolts were liberated on 23rd April and from then until the end of the run approximately 8,650 wild smolts passed downstream. If the results from the hatchery-reared smolts are an indication of movements of the wild smolts, it could be inferred that roughly 960 wild smolts from the Meig impoundment passed through the tunnel, that is, that the total run at Meig for 1958 should be increased to about 10,000 smolts.

An inspection of the smolt screens at the entrance to the Meig-Luichart tunnel later in 1958 revealed that there were gaps at the ends of the screens big enough to allow the passage of smolts. Modifications were therefore made to these screens to close these gaps before the smolt run of 1959. Tagged, hatchery-reared smolts were again liberated in the Meig impoundment in 1959, but records of their recapture again showed that some had passed into Loch Luichart. (The escape route this time was probably by gaps below the screens, which were present because, due to the presence of trash, some of the lowermost screens were not bedded properly. Also approximately 300 smolts were found dead in the compensation turbine at Meig dam which is supplied by water drawn from behind the smolt screens). The recaptures of tagged, hatchery-reared smolts suggested that roughly 2,500 smolts passed into Loch Luichart so that the smolt run at Meig should be increased to about 12,900 smolts or, if allowance is also made for the deaths in the compensation turbine, to about 13,200 smolts.

Arrangements were then made to ensure that all the screens were bedded properly, but the smolt run in 1960 was the lowest yet recorded at the Meig trap. One reason for the low total may be that, when the Meig impoundment was de-watered in December 1959 and February 1960 some parr, which would have formed part of the 1960 smolt migration, were washed downstream. This suggestion is supported by the records of the numbers of parr passing through the Meig trap during December 1959 and February 1960 (Table 1). Another reason for the low total is that, although the gaps at the ends of the screens had been blocked and every care had been taken to ensure that the screens were bedded properly, there was evidence that some had passed from Meig to Luichart. Unfortunately, it is not easy to assess the value of this evidence accurately. As in previous years, tagged, hatchery-reared smolts were liberated just above Meig dam and roughly 8% of the fish recaptured were taken in the Luichart system. It is not certain, however, that this result is representative, for the following reasons:

(*a*) A spill occurred at Meig the day after the hatchery-reared smolts were added, so that some may have been carried past the Meig trap, which was out of action for nearly 48 hours. A spill also occurred in the Luichart system but this was neither so extensive nor so prolonged so that the Meig recaptures of the tagged smolts may have been affected more than those at Luichart.

*(b)* One of the screens at the entrance to the Meig-Luichart tunnel was found to be damaged on 13th April (two days after the hatchery-reared fish had been added). This screen was removed and a substitute was not fitted until 14th April. Thus, for a short period immediately following the release of tagged smolts in the Meig impoundment the entrance to the tunnel was not completely screened. This could, clearly, have had an important effect, perhaps particularly on the route taken by the hatchery-reared smolts.

*(c)* In order to obtain direct evidence of the passage of young fish through the Meig-Luichart tunnel, a box trap was placed behind the smolt screens at the entrance to this tunnel on 5th May. Between that date and 20th June, when this trap was removed after it had been damaged by a flood, 45 smolts were caught. The Meig trap records, however, show that, during this period, about 6,250 smolts passed down the Meig. Thus on this evidence only about 0·7% of the Meig smolts passed into the Luichart system. Because of the evidence set out in *(a)* and *(b)* above, it seems more reasonable to accept this estimate of the proportion of Meig smolts which migrated into the Luichart system, rather than that obtained from the recapture of tagged, hatchery-reared fish. Using this correction factor, the smolt run at Meig in 1960 perhaps should be increased to 7,250.

Thus there is evidence for amending the totals given in Table 2 and the amended totals (in round figures) are shown in brackets. The corresponding adjustments in the smolt catches at the Luichart trap have been similarly entered in Table 3.

The numbers of smolts caught at the Luichart trap are shown in Table 3. The records from this trap are less regular than those obtained at Meig. In 1957, when the total smolt run only amounted to some 350 fish, smolts were migrating in small numbers over the period from the last week in April until about the middle of June but in 1958 and 1959, when the total number of smolts recorded (approximately 1,950 and 3,300 respectively) was much greater, there was rather more evidence of a definite run. In 1958 this covered the last two weeks of May and the first week of June and in 1959 it extended over May and the first half of June. In 1960, when the size of the run was again reduced, about three-quarters of the smolts moved downstream between mid-May and mid-June.

As has been mentioned already, the small number of smolts caught at the Luichart trap over the early part of the season in 1957 gave rise to serious concern, because in 1955 and in 1956 it had been suspected that smolts arriving at the lower end of Loch Luichart could not easily discover the exit which led to the Borland lift. This exit is not built into the face of the dam but lies to one side of a structure which projects about 25 yds into Loch Luichart. Observations had shown that, although small numbers of smolts were passing downstream, others could be seen swimming along the upstream face of the dam. During the early months of 1957, therefore, an attempt was made to facilitate the passage of smolts from Loch Luichart by providing an alternative route to the Borland fish lift. Sluices were constructed at each end of the dam and, when these were opened, water was discharged from the face of the dam. The water released in this way ran down chutes and small pools were constructed at the base of each chute, so that the fish using this means of exit from the loch could be examined, counted and, if necessary, marked. It was hoped that the chutes would provide an alternative downstream route which could be used by those smolts which missed the entrance to the fish lift and which congregated along the upstream face of the dam.

The chutes were completed on 6th June 1957 and have since been in operation from April to November each year. They are dismantled and stored during the winter and early spring. To assess the relative efficiency of these chutes and the Borland fish lift, the normal routine of operation has been that for a period of 72 hours the lift was shut off and the chutes were put into operation and then, for the succeeding 72 hours the lift was in operation and the chute sluices were closed. This routine has been followed as regularly as possible, but there have been periods when the water level in Loch Luichart was too low to allow the chutes to be used.

Details of the records obtained from these chutes are given in Table 4. A comparison of the second and fourth columns in this table would suggest that, at least in 1957, 1959 and 1960, most of the smolts which were caught in the Luichart trap had left the loch above by means of these chutes, whereas in 1958 the proportion using the Borland lift was apparently much greater. A comparison of the second and third columns in this table, however, indicates that only a small proportion of the fish which descended

the chutes, all of which were marked in the pools at the foot of these structures, were subsequently caught in the trap, and the discrepancy between the figures in the second and third columns indicates that there must be serious losses between the pools at the foot of the chutes and the trap. The distance involved is only 400 yards, but it would seem that most of the smolts do not succeed in traversing it. If marked hatchery-reared smolts are introduced below the dam, however, a high proportion (at least 70%) reach the trap. This suggests that serious losses between the chute pools and trap occur because of damage sustained by the smolts on their passage from the loch rather than because of any major difficulty in traversing the short distance between the dam and the traps. The records given in Table 4 do, however, indicate that most of the smolts which reached the Luichart trap had left Loch Luichart by means of the Borland lift (the proportion ranges from 74% in 1960 to 91% in 1958). In fact, the Borland lift may well have been a more effective means of exit for smolts than was realised in 1957.

Thus the records of smolts at the Luichart trap are far from easy to interpret but it seems quite certain that, for reasons given later, the number is far fewer than the estimated smolt production from the River Bran.

The sex of a proportion of the smolts passing downstream through the two traps was determined. The results show that there is generally a slight preponderance of females as the ratio of females:males for the smolts at the Meig trap ranges from 1·3:1 to 1·1:1, whereas the ratios at Luichart range from 1·8:1 to 1·0:1. These ratios agree closely with those given by Europiezewa (1957).

The lengths of a proportion of the smolts passing through each trap have been measured throughout the period of this investigation. The full details have been filed for reference but a representative sample of the kind of results obtained is given in Table 5, which shows the records for the Meig trap in 1957 and 1958. From this table it will be seen that the mean length gradually increases through the spring and early summer. A gradual increase in the lengths of the migrants as the season progresses is, of course, to be expected but the rate of growth of the fish in the impoundment above the Meig trap may have been unusually rapid because of the favourable conditions created by the flooding produced when the River Meig was impounded by the dam. Some of the smolts migrating early in the season were exceptionally large and it seems probable that these were older fish which had perhaps not migrated earlier because of the conditions produced by the dam. An examination of the scales of the largest fish recorded in this table (33·5 cm. long caught between 14th and 27th April) showed that this fish was 4+ years old. In this connection it should be mentioned that the mean lengths of smolts taken in the Luichart trap during 1956 were unusually high, since these values for the period April-August (inclusive) ranged from 20·5 cm. to 25·0 cm. Again, it may be presumed that these were older fish which could not, or did not, migrate in earlier years.

All the scale samples collected over the period 1957 to 1959 have not yet been read, so it is not possible to give a full analysis of the age composition of the smolts migrating during this period, but present results agree with those of Menzies (1928) who has shown that smolts from the Conon River system generally are rather older than those from many east Scottish rivers, and that 53% of the migrants were three years old, 42% two years old, 4% four years old and a few five years old when they migrated to sea.

A preliminary indication of the rate of growth of smolts in the system, from the scales which have been read so far, is given in Table 6.

Details of the numbers of smolts tagged are set out in Table 7. This table calls for little comment except that the small proportion of smolts tagged at Luichart in 1959 was due to the poor condition of many of the migrants passing through the trap in that year. The wider range of types of tag used in 1959 arises because the opportunity was taken to test some of the types of tag which are being used in the International Comparative Tagging Tests (the preliminary results of these tests are given in Table 12, p. 24).

A small percentage (0·53% in 1957, 1·72% in 1958, 0·38% in 1959 and 0·28% in 1960) of the smolts were affected with an eye condition which resulted in one or both eyes protruding. This condition was especially evident at the Meig trap. The eyes affected sometimes became covered with fungus which gave the fish the appearance of wearing goggles and in a few cases the eye dropped out of its socket. Affected fish were usually dark in colour and had abnormally slow reactions. Microscopic examination

of the eyes of affected fish did not reveal the cause of the condition and only fungal hyphae could be seen in sections. This disease is possibly the same as that described by Europiezewa (1957).

(*c*) Adults

Weekly records of the numbers of adults passing through the traps at Meig and Luichart are given in Tables 8 and 9. These tables cover the period May to October (inclusive) which includes the main period of the upstream run. From Table 8 it can be seen that the maximum numbers pass upstream during August, though the run during September is also appreciable. At Luichart (Table 9) again most of the fish pass into the trap during August, though fair numbers are captured during September and, in 1959, during October. The total upstream run at Meig numbered just over 600 fish in 1957 but during the following two years the total was less than half this (256 and 246 respectively) and the run in 1960 was slightly smaller still. The outstanding feature of the Luichart records is the sharp increase in the numbers entering the trap during 1959 when, for the first time, the numbers in this trap exceeded those at Meig. In 1960, the upstream run at Luichart was again bigger than that at Meig. This point is discussed on pp. 15 and 16.

Records have also been kept of the numbers of fish which, having passed through the Meig trap, went up the Borland lift at the Meig dam and entered the impoundment upstream. In 1957 and 1958 there was a substantial discrepancy between the two totals as the proportions counted into the impoundment were only 70% and 76% respectively of the numbers which had passed through the trap. The subsequent history of those which did not pass on into the impoundment is not known completely, but some died and some spawned between the trap and the dam. In 1959, however, a much higher proportion of the run (93%) passed on and, in 1960, nearly all (99%) of the fish which passed through the trap also passed on into the Meig. The reason for this improvement is not certainly known but it may be connected with the installation of a counter at the foot of the Borland lift at Meig dam in 1959. This installation involved the construction of pools below the counter and it seems possible that the existence of these pools allowed fish which had not passed into the impoundment at the first opportunity to remain in the immediate vicinity of the entrance to the lift afterwards.

As has been mentioned earlier, adult fish have not, during most of the period of this survey, been allowed to pass beyond the Luichart trap. Before 1960, all the fish caught in this trap were marked and released again downstream. It was found that many of them re-entered the trap during subsequent weeks and that some fish re-appeared several times. The detailed records of the re-appearance of these fish released downstream also suggest that there may be some increase in the persistence of upstream movement as the season progresses. It is interesting to note that, over the period from August 1960, a discrepancy developed between the numbers of fish passed through the Luichart trap and those passing on into Loch Luichart which was of a similar order to that found at Meig in 1957.

Records have been kept of the sex ratio of the adult fish passing into both traps. The general result is that there are rather more males then females in the runs (see Table 10) but there may be a preponderance of females for short periods during the runs (1957-59) or an overall preponderance of females (1960). Alm (1934) and Azbelev and Lagunov (1958) found that females predominated in runs of Atlantic salmon and this characteristic has been found by other workers for the spawning runs of other salmonids e.g. sockeye salmon (Foerster, 1954); sea trout (Alm, 1950); brown trout (Hobbs, 1937; Munro and Balmain, 1956), but Stuart (1953) found that in the spawning runs of brown trout from Dunalastair Reservoir males were always more numerous than females overall. Menzies (1931, p. 79) mentions that males may predominate in runs of grilse and, as the major part of the run at Meig and Luichart consists of grilse, this may explain the preponderance of males in the runs into these two traps.

The details of weight and length, determined as set out on pp. 7-8 have been filed but they do not call for detailed discussion here. The length measurements, are, however, important because it has been possible to show that there is a relationship between the number of eggs in the ovary and the length of the female fish. This relationship is:

$$\log_{10}N = 2{\cdot}3345 \log_{10}L - 0{\cdot}533$$

where N=number of eggs, L=length (in cm.).

Details of this aspect of the work have been published separately (Pope, Mills and Shearer, 1961).

Although no correlation could be found between either air and water temperatures, barometric pressure or rainfall and the upstream movement of adult fish, there was a general impression that most fish entered the traps during rainy weather. Munro and Balmain (1956) pointed out that the runs of brown trout in the South Queich (Loch Leven) always began after an increase in water level and other workers, e.g. Nall (1930) and Lamond (1916) for sea trout and Menzies (1936) for brown trout, also found that a rise in water level induces upstream movement.

Because the water flowing downstream through the traps was regulated, rainfall did not result in a rise in water level either at Meig or Luichart, but attempts have been made, by arranging artificial freshets, to see whether an increase in water flow stimulated upstream movement. Table 11 summarises the results of one experiment of this kind. During this period the flow over the Meig trap was increased from the standard flow of 37 cusecs to a maximum of 121 cusecs over a series of 12-hour periods and then decreased again in the same way. The experiment was arranged so that one of the 12-hour periods for each speed of flow took place during the night and the other during the day. The results given in Table 11 do not suggest that there is a correlation between the rate of flow in these artificial freshets and upstream movement and this is the impression gained by a number of experiments of this kind. In fact, it seemed that heavy rain increasing the flow from a burn just above the Meig trap was a greater inducement to fish movement than artificial freshets. Hayes (1953), working on the La Have River, also found that artificial freshets had little effect on upstream movements compared with the effects of rain.

The fish caught in the Meig trap have, during 1958 and 1959, included some which had been tagged as smolts in previous years. These recaptures, together with others, are shown in Table 12. As this table shows, the number of recaptures has been very small. It is encouraging to note the increase in the number of recaptures recorded during 1959 and 1960 and this may well have been one of the results of the employment of a special watcher during the netting season those two years, who was able to scrutinise each fish caught in the nets in the estuary.

(*d*) Kelts

Details of the kelts caught at the Meig trap are given in Table 13. It is probable that these records are not complete, since the period of the year over which kelts are moving downstream is also a period at which spills from the impoundment upstream are most likely to take place, putting the trap out of action. This may be one reason for the substantial difference recorded between the numbers of kelts descending and the numbers of adults moving upstream during the previous summer. As is shown in Table 13, in 1957-58 the number of kelts passing downstream represented about a quarter of the adults which passed upstream, but during 1958-59 and 1959-60 it was only possible to account for just over one-tenth of the adults which passed upstream during the preceding summers.

Nevertheless, these imperfect records agree with the records given in the report on 'The passage of smolts and kelts through fish passes', which was published by the Scottish Home Department in 1957 and which gives records of the downstream movement of kelts at Pitlochry. There it was found that most of the kelts moved downstream in November or December or delayed their descent until much later (April or May). The records from the Meig trap, particularly in 1957-58 when larger numbers of kelts were recorded, confirm the earlier records.

Observations in the impoundment near the dam suggest that the latter has an effect on the downstream movement of kelts. It has not been possible to record this effect precisely, but on a number of occasions either kelts have been seen just above the dam and none have been recorded in the trap subsequently or the numbers recorded in the trap were less than the fish seen in the dam. For example on 9th May, 1959, 35 kelts were seen in the impoundment near Meig dam, but only 14 kelts were subsequently caught in the trap.

(*e*) Predators

A number of instances of predation have been noted during the period reviewed in this report and the chief predators are mentioned below.

Smolts have been found in the stomachs of brown trout and pike on many occasions and smolt tags have been recovered from brown trout up to 65 days after the smolts carrying them were released.

Black-headed gulls (*Larus ridibundus*) and common gulls (*Larus canus*) have been found to take smolts under circumstances where the fish might well have been particularly visible near the surface, for example, immediately after liberation from the traps after tagging, in confined pools, or sometimes, when brought to the surface in turbulent water. The hooded-crow (*Corvus cornix*) has been seen to take smolts as they were washed on to the grid of the Meig trap and herons (*Ardea cinerea*) have occasionally visited the smolt traps.

Parr and smolts have been found in the stomachs of goosanders (*Mergus merganser*), red-breasted mergansers (*Mergus serrator*) and cormorants (*Phalacocorax carbo*) shot in the area. The stomachs of two goosanders contained respectively 36 and 14 smolt tags.

Otters (*Lutra lutra*) have been known to take smolts. A tag and the remains of a smolt were found in the stomach of one otter and 8 tags have been found in otter droppings. Otters have also been responsible for the death of a number of kelts and may also have been responsible for the death of some ascending fish.

## DISCUSSION

The original aim of the work on the Conon River system was to compare the smolt production from a stream in which salmon spawned naturally (the Meig) with that from a stream which was stocked with unfed fry (the Bran). There are two reasons why it has not been possible to make this comparison with any accuracy. First, the existence of a connection between the two systems (the Meig-Luichart tunnel) makes it possible for smolts to migrate from one river system to the other and there is evidence that the numbers of smolts passing through the Meig trap have been depleted and those passing through the Luichart trap have been augmented in this way (see p. 10). Second, an investigation of the conditions on the River Bran has shown that the numbers of smolts passing through the Luichart trap is not an accurate measure of the smolt production of the Bran (Mills, in the press) because serious losses occur between the lower reaches of the Bran and the Luichart trap.

To some extent, the difficulties mentioned in the previous paragraph arise because of hydro-electric developments on this river system. Other complications produced by hydro-electric developments in a river system are illustrated by some of the other results reported in this paper.

The effects of hydro-electric developments may be grouped under three headings:

(*a*) Fundamental disturbances produced by (i) the erection of dams and the creation of impoundments and (ii) the diversion of water from one river to the other. These are major changes which may well have permanent effects.

(*b*) Disturbances arising from imperfections in the arrangements made to facilitate upstream or control downstream movements or to prevent fish entering areas known to be dangerous. These disturbances are likely to occur most often during the first few years the new installations are operating.

(*c*) Disturbances from operations connected with the care and maintenance of the hydro-electric installations. These disturbances are likely to be occasional but persistent.

It is unfortunately not possible to estimate the overall effect of the first type of disturbance just mentioned. In common with nearly all Scottish rivers, information on the stocks and the numerical strength of the main migrations of salmon of the Conon system before hydro-electric development is not available in enough detail to compare present conditions with those prevailing before modification.

Instances of less radical changes have, however, been observed, such as, for example, changes in the upstream runs of adult fish. In 1957 and 1958 the adult run at the Meig trap was larger than that recorded at the Luichart trap, but in 1959 and 1960 this relationship was reversed.

A number of suggestions can be put forward to explain this change, including:

(*a*) The effect of the operation of Luichart power station. When this station is working, the flow from the Conon is much greater than that from the Meig and this may result in more fish moving into the stronger flow (Hourston, 1958). It is difficult, however, to understand why this effect should have occurred in 1959 and 1960 but not in 1957 and 1958.

(*b*) Because the flow from the Conon contains varying amounts of water from the Meig, if upstream migrants respond to characteristic tastes or odours in the water (Hasler, 1954; Hasler and Wisby, 1951;

Wisby and Hasler, 1954) they may respond to the 'Meig taste' in the outflow from the Conon. On the other hand this 'taste' must always be stronger in the water from the Meig so that, on this basis, fish should have entered the Meig rather than the Conon.

(*c*) It has been shown that, in 1958 and 1959, the smolt run in the Conon was supplemented significantly by smolts from the Meig system. Pantulu (1959) has produced evidence that salmon tend to follow the same route upstream as adults as that they followed downstream as smolts. This, therefore, may be the explanation of the increases in the adult runs at Luichart in 1959 and 1960 but the fact remains that most of the Meig smolts migrated down the Meig rather than the Conon and therefore big differences were not to be expected in the upstream runs through the Luichart trap.

It would seem, however, unprofitable to speculate too widely because the changes in the upstream runs through the Meig and Luichart traps may not be connected with hydro-electric developments. There is no detailed information about the relative strengths of runs into the various tributaries, from year to year, of a river system which has not been affected by hydro-electric developments, so the possibility remains that the changes recorded at Meig and Luichart may have parallels in other river systems.

The records of smolt runs at Luichart supply examples of the second type of disturbance mentioned earlier. In 1957 the smolt run at this trap was very small but in 1958 and, particularly, in 1959 it was considerably larger. In 1960, however, the run was again small (though larger than in 1957). As has been mentioned there is evidence that the Luichart smolt run in 1958 and 1959 was supplemented by smolts from the Meig impoundment and there is good reason to suppose that smolts had been able to pass into the Meig-Luichart tunnel either round the ends of the smolt screens (in 1958) or, because of imperfect bedding, below the screens (in 1959). Before the smolt run of 1960, particular care was taken to ensure that the smolt screens at Meig dam fitted tightly and were bedded properly and, there is no reason to suppose that many smolts moved through the tunnel during the spring migration.

Finally, the records of parr movements during the winter of 1959-60 may well be examples of the effects of the third type of disturbance. Because modifications were necessary at Meig dam, the impoundment was de-watered twice during that winter and large numbers of parr recorded in December 1959 and February 1960 are almost certainly connected with these operations.

Hydro-electric developments may produce marked changes in a river system and it is difficult to see how these can fail to affect the movements of migratory fish. The problems which these changes pose are not likely to be solved quickly, because their solution demands knowledge of the physiology and behaviour of salmon which is at present lacking, though research on these subjects is proceeding actively in this country and in North America. Even if these researches are wholly successful and ways are found of solving these problems, some of the records reviewed in this paper indicate there are other effects of hydro-electric developments, perhaps less obvious but by no means insignificant, which are likely to affect salmonid stocks and movements. Great care must be taken, for example, to ensure that all protective structures are properly adjusted and fully effective and that care and maintenance operations are planned so as to interfere as little as possible with fish movements. The operation of the traps on the Conon system has made it possible to detect the effects of badly-adjusted screens or de-watering immediately but, as checks of this kind are not practicable on every river affected by hydro-electric developments, similar instances elsewhere may go undetected. Under such circumstances, even greater care is needed and it is hoped that these records from the Conon system will have indicated at least some of the other effects which may occur.

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## SUMMARY

1. An account is given of the records made at two traps on the Conon River system (Ross-shire) during the period 1957-1960. One of these traps is situated on the River Meig, which is stocked naturally and the other on the River Conon below Loch Luichart. The main system above the latter loch is artificially stocked.

2. Details are given of the capture of smolts and adults at each trap; these details seem reasonably complete. Details are also given of the parr and kelts caught at the Meig trap; these are almost certainly incomplete.

3. The smolt run at the Meig trap during 1957 totalled roughly 14,000 smolts. During the following two years the totals were substantially smaller (9000 and 10,400 respectively) and smaller still in 1960, when the total was about 7000 smolts. At the Luichart trap in 1957 the smolt run was very small (roughly 300 fish) but in 1958 (1900 fish) and in 1959 (roughly 3300 fish) the runs were larger. There is, however, evidence which indicates that the smolt run at Luichart was supplemented by smolts from the Meig in 1958 and 1959. In 1960, when there was no evidence of supplementation, the smolt run at Luichart was 1000 fish.

4. A proportion of the smolts passing through each trap was tagged. At Meig this proportion did not exceed 34%. At Luichart the proportion was as high as 63% in 1957, but in 1959 only 16% of the smolts passing through the Luichart trap were tagged. The proportionate recapture of tagged smolts as adults has been low, the highest return recorded so far being 1·1% from the smolts tagged at Luichart in 1960.

5. The upstream run of adult fish at Meig was much higher in 1957 (when it totalled just over 600 fish) than in either 1958, 1959 or 1960 when 200-250 fish moved upstream. The outstanding feature of the adult runs at Luichart has been the considerable increases in 1959 and 1960 when the upstream runs totalled 269 and 289 respectively.

6. Though records have been kept of the kelts passing through the Meig trap they are almost certainly incomplete. The number of kelts passing downstream during 1957-58 represented about 25% of the upstream run the previous summer, whereas in the following winters only about 10% of the corresponding upstream runs were recorded as kelts.

7. The records obtained provide useful evidence on the movements of salmon in streams affected by hydro-electric developments and the general effects of such developments are discussed.

## REFERENCES


ALLEN, K. R. 1944. 'Studies on the biology of the early stages of the salmon (*Salmo salar*). 4. The smolt migration in the Thurso River in 1938.' J. Anim. Ecol., **13**, 63-85.

ALM, G. 1934. 'Salmon in the Baltic precincts.' Rapp. Cons. Explor. Mer, **92**, 1-63.

ALM, G. 1950. 'The sea trout population in the Ava stream.' Rep. Inst. Freshw. Res. Drottning., 31, 26-36.

AZBELEV, V. V. and LAGUNOV, I. I. 1958. 'On the sex ratio in *Salmo salar*.' Zool. Zhurn., **37**, 1515-20.

BERRY, J. 1932. 'The trapping of spawning trout.' Salm. Trout Mag., 67, 199-24.

BERRY, J. 1933. 'Notes on the migration of salmon smolts from Loch Ness, Summer, 1932.' Fisheries, Scotland, Salmon Fish., 1933, I, 12 pp.

BULL, H. O. 1931a. 'The smolt descent on the River Tyne.' Rep. Dove Mar. Lab., 1930, 37-66.

BULL, H. O. 1931b. 'The smolt descent on the River Tyne, 1931.' Rep. Dove Mar. Lab., 1931, 32-43.

CALDERWOOD, W. L. 1906. 'Autumn migration of smolts in Scotland.' Rep. Fish. Bd Scot., 1905, Part II, 70-74.

EUROPEIZEWA, N. V. 1957. 'Transformation to smolt stage and downstream migration of young salmon.' Vehenyi Zapidski Leningradskova Gosudarstvennova Universitata (LGU), 228, Seria Biologioheskikh Nauk, **44**, 117-54.

FOERSTER, R. E. 1929a. 'An investigation of the life history and propagation of the sockeye salmon (*Oncorhynchus nerka*) at Cultus Lake, British Columbia. No. 1. Introduction and run of 1925.' Contr. Canad. Biol., **5**, 1-35.

FOERSTER, R. E. 1929b. 'An investigation of the life history and propagation of the sockeye salmon (*Oncorhynchus nerka*) at Cultus Lake, British Columbia. No. 2. The run of 1926.' Contr. Canad. Biol., **5**, 39-53.

FOERSTER, R. E. 1929c. 'An investigation of the life history and propagation of the sockeye salmon (*Oncorhynchus nerka*) at Cultus Lake, British Columbia. No. 3. The downstream migration of the young in 1926 and 1927.' Contr. Canad. Biol., **5**, 57-82.

FOERSTER, R. E. 1934. 'An investigation of the life history and propagation of the sockeye salmon (*Oncorhynchus nerka*) at Cultus Lake, British Columbia. No. 4. The life history cycle of the 1925 year class with natural propagation., Contr., Canad. Biol., **8**, 347-55.

FOERSTER, R. E. 1954. 'Sex ratios in sockeye salmon (*Oncorhynchus nerka*).' J. Fish. Res. Bd Can., **11**, 988-97.

HASLER, A. D. 1954. 'Odor perception and orientation in fishes.' J. Fish. Res. Bd Can., **11**, 107-29.

HASLER, A. D. and WISBY, W. J. 1951. 'Discrimination of stream odors by fishes and its relation to parent stream behaviour.' Amer. Nat., **85**, 223-38.

HAYES, F. R. 1953. 'Artificial freshets and other factors controlling the ascent and population of Atlantic salmon in the La Have River, Nova Scotia.' Bull. Fish. Res. Bd Can., 99, 47 pp.

HOBBS, D. F. 1937. 'Natural reproduction of quinnat salmon, brown and rainbow trout.' New Zealand, Marine Department, Fisheries Bulletin, 6, 104 pp.

HOURSTON, W. R. 1958. 'Power developments and anadromous fish in British Columbia.' From 'The investigation of fish power problems' (edt. P. A. Larkin), 15-24.

LAMOND, H. 1916. *The Sea Trout,* pp. xi+219, London: Sherrat and Hughes.

MENZIES, W. J. M. 1928. 'Salmon of the River Conon, 1927.' Fisheries, Scotland, Salmon Fish., 1928, VIII, 17 pp.

MENZIES, W. J. M. 1931. *The Salmon, its Life Story,* pp. xiv+213, Edinburgh: William Blackwood.

MENZIES, W. J. M. 1936. *Sea Trout and Trout,* pp. 230, London: Edward Arnold.

MILLS, D. H. (in the press) 'The ecology of the young stages of the Atlantic salmon in the River Bran, Ross-shire.' Sci. Invest. Freshwat. Fish. Scot., 32.

MUNRO, W. R. and BALMAIN, K. H. 1956. 'Observations on the spawning runs of brown trout in the South Queich, Loch Leven.' Sci. Invest. Freshwat. Fish. Scot., 13, 17 pp.

NALL, G. H. 1930. *The Life of the Sea Trout,* pp. 235, London: Seeley, Service.

PANTULU, V. R. 1959. 'Effects of hydro-electric developments on the fresh water fisheries of British Columbia.' Canad. Fish Cult., 25, 12-23.

POPE, J. A., MILLS, D. H. and SHEARER, W. M. 1961. 'The fecundity of Atlantic salmon (*Salmo salar* Linn.).' Sci. Invest. Freshwat. Fish. Scot., 26, 12 pp.

SAUNDERS, J. W. 1960. 'The effect of impoundment on the population and movement of Atlantic salmon in Ellerslie Brook, Prince Edward Island.' J. Fish. Res. Bd Can., **17**, 453-73.

STUART, T. A. 1953. 'Spawning migration, reproduction and young stages of loch trout (*Salmo trutta* L.).' Sci. Invest. Freshwat. Fish. Scot., 5, 39 pp.

WHITE, H. C. 1940. 'Factors influencing descent of Atlantic salmon smolts.' J. Fish. Res. Bd Can., **4**, 323-26.

WHITE, H. C. and HUNTSMAN, A. G. 1938. 'Is local behaviour in salmon heritable?' J. Fish. Res. Bd Can., **4**, 1-18.

WISBY, W. J. and HASLER, A. D. 1954. 'Effect of olfactory occlusion on migrating silver salmon (*O. kisutch*).' J. Fish. Res. Bd Can., **11**, 472-78.

TABLE 1

Numbers of parr caught at the Meig trap

| Month | Year | | | |
|---|---|---|---|---|
| | 1957 | 1958 | 1959 | 1960 |
| January | – | 13 | 6 | 17 |
| February | – | 2 | 25 | 164 |
| March | – | 5[a] | 11 | 24 |
| April | 21 | 16[b] | 116 | 104 |
| May | 0 | 5 | 10 | 86 |
| June | 0 | 5 | 3 | 0 |
| July | 16 | 1 | 2 | 0 |
| August | 14 | 14 | 11 | 48[c] |
| September | 107 | 18 | 8 | 42[d] |
| October | 25 | 77 | 26 | 23 |
| November | 54 | 17 | 37 | 18 |
| December | 26 | 15 | 271 | 6 |

– indicates trap not in operation
[a] March 1-20 only
[b] from April 12
[c] small-meshed wire gauze fitted to smolt grid from August 19
[d] three fry also entered the trap.

TABLE 2

Numbers of smolts caught at the Meig trap

| 1957 | | 1958 | | 1959 | | 1960 | |
|---|---|---|---|---|---|---|---|
| Wk. Ending | No. | Wk. Ending | No. | Wk. Ending | No. | Wk. Ending | No. |
| April 6 | 0 | April 5 | – | April 4 | 16 | April 2 | 0 |
| 13 | 12 | 12 | – | 11 | 140 | 9 | 4 |
| 20 | 162 | 19 | 170 | 18 | 91 | 16 | 5 |
| 27 | 341 | 26 | 227 | 25 | 108 | 23 | 80 |
| May 4 | 101 | May 3 | 135 | May 2 | 1,585 | 30 | 145 |
| 11 | 88 | 10 | 1,885 | 9 | 2,371 | May 7 | 147 |
| 18 | 857 | 17 | 1,541 | 16 | 2,581 | 14 | 332 |
| 25 | 4,515 | 24 | 2,956 | 23 | 1,363 | 21 | 3,865 |
| June 1 | 3,050 | 31 | 527 | 30 | 1,259 | 28 | 847 |
| 8 | 2,262 | June 7 | 71 | June 6 | 118 | June 4 | 760 |
| 15 | 425 | 14 | 347 | 13 | 530 | 11 | 727 |
| 22 | 391 | 21 | 308 | 20 | 33 | 18 | 213 |
| 29 | 917 | 28 | 586 | 27 | 10 | 25 | 26 |
| July 6 | 313 | July 5 | 113 | July 4 | 12 | July 2 | 2 |
| 13 | 353 | 12 | 19 | 11 | 12 | 9 | 1 |
| 20 | 94 | 19 | 13 | 18 | 131 | 16 | 0 |
| 27 | 43 | 26 | 10 | 25 | 1 | 23 | 5 |
| Aug. 3 | 5 | Aug. 2 | 19 | Aug. 1 | 2 | 30 | 0 |
| 10 | 3 | 9 | 74 | 8 | 0 | Aug. 6 | 3 |
| 17 | 8 | 16 | 19 | 15 | 0 | 13 | 10 |
| 24 | 3 | 23 | 1 | 22 | 0 | 20 | 13 |
| 31 | 0 | 30 | 0 | 29 | 0 | 27 | 7 |
| Sept. 7 | 0 | Sept. 6 | 0 | Sept. 5 | 0 | Sept. 3 | 3 |
| 14 | 0 | 13 | 16 | 12 | 0 | 10 | 3 |
| 21 | 0 | 20 | 0 | 19 | 0 | 17 | 2 |
| 28 | 0 | 27 | 2 | 26 | 0 | 24 | 1 |
| Totals | 13,943 | | 9,030 | | 10,363 | | 7,201 |
| Total Runs[a] | 13,943 (14,000) | | 9,047 (10,000) | | 10,367 (13,200) | | 7,202 (7,250) |

– indicates trap not in operation
[a] including the fish migrating outside the period detailed in this table.
The figures in brackets indicate the adjusted totals (in round figures), see text.

TABLE 3

Numbers of Smolts caught at the Luichart trap

| 1957 Wk. Ending | No. | 1958 Wk. Ending | No. | 1959 Wk. Ending | No. | 1960 Wk. Ending | No. |
|---|---|---|---|---|---|---|---|
| April 6 | – | April 5 | 0 | April 4 | 0 | April 2 | 0 |
| 13 | – | 12 | 1 | 11 | 0 | 9 | 0 |
| 20 | 0 | 19 | 2 | 18 | 0 | 16 | 0 |
| 27 | 10 | 26 | 19 | 25 | 0 | 23 | 4 |
| May 4 | 26 | May 3 | 20 | May 2 | 201 | 30 | 9 |
| 11 | 43 | 10 | 82 | 9 | 430 | May 7 | 34 |
| 18 | 25 | 17 | 91 | 16 | 285 | 14 | 94 |
| 25 | 45 | 24 | 345 | 23 | 617 | 21 | 230 |
| June 1 | 12 | 31 | 596 | 30 | 1,020 | 28 | 218 |
| 8 | 56 | June 7 | 386 | June 6 | 305 | June 4 | 142 |
| 15 | 25 | 14 | 137 | 13 | 326 | 11 | 186 |
| 22 | 44 | 21 | 53 | 20 | 15 | 18 | 25 |
| 29 | 6 | 28 | 146 | 27 | 7 | 25 | 4 |
| July 6 | 2 | July 5 | 11 | July 4 | 7 | July 2 | 4 |
| 13 | 8 | 12 | 9 | 11 | 6 | 9 | 5 |
| 20 | 0 | 19 | 4 | 18 | 41 | 16 | 8 |
| 27 | 0 | 26 | 30 | 25 | 11 | 23 | 6 |
| Aug. 3 | 1 | Aug. 2 | 6 | Aug. 1 | 4 | 30 | 5 |
| 10 | 0 | 9 | 1 | 8 | 4 | Aug. 6 | 2 |
| 17 | 2 | 16 | 2 | 15 | 1 | 13 | 4 |
| 24 | 0 | 23 | 2 | 22 | 1 | 20 | 3 |
| 31 | 0 | 30 | 1 | 29 | 1 | 27 | 2 |
| Sept. 7 | 1 | Sept. 6 | 0 | Sept. 5 | 0 | Sept. 3 | 10 |
| 14 | 2 | 13 | 0 | 12 | 1 | 10 | 2 |
| 21 | 1 | 20 | 1 | 19 | 0 | 17 | 0 |
| 28 | 0 | 27 | 0 | 26 | 0 | 24 | 1 |
| Totals | 309 | | 1,945 | | 3,283 | | 998 |
| Total Runs[a] | 354 (350) | | 1,946 (1,000) | | 3,287 (750) | | 1,000 (950) |

– indicates trap not in operation

[a] see note to Table 2.

TABLE 4

Smolts descending the Chutes at Luichart Dam

| Year | No. descending chutes | No. subsequently caught in trap | Total number caught in trap |
|---|---|---|---|
| 1957 | 236 | 52 | 354 |
| 1958 | 438 | 166 | 1,946 |
| 1959 | 2,405[a] | 389 | 3,287 |
| 1960 | 939 | 258 | 1,000 |

[a] Of these, 97 died in the pools at the foot of the chutes.

TABLE 5

Lengths of Smolts caught at the Meig trap, 1957 and 1958

| Period | No. Examined | Mean Length (cm.) | Mean Standard Error |
|---|---|---|---|
| 1957 | | | |
| April 16-30 | 74 | 12·8 | ± 0.118 |
| May 1-14 | 46 | 12·5 | ± 0.150 |
| May 15-28 | 314 | 13·5 | ± 0.080 |
| May 29–June 11 | 90 | 14·7 | ± 0.163 |
| June 12-25 | 135 | 15·6 | ± 0.127 |
| June 26–July 9 | 54 | 17·5 | ± 0.137 |
| 1958 | | | |
| April 14-27 | 155 | 12·5 | ± 0.229 |
| April 28–May 11 | 359 | 13·8 | ± 0.101 |
| May 12-25 | 383 | 13·5 | ± 0.090 |
| May 26–June 8 | 30 | 14·3 | ± 0.317 |
| June 9-22 | 23 | 15·1 | ± 0.543 |
| June 23–July 6 | 81 | 15·5 | ± 0.260 |

TABLE 6

Rate of Growth of Smolts

| Age at Migration | Length (cm.) at end of winters | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 2 | 4·6 | 11·6 | – | – |
| 3 | 3·9 | 8·3 | 13·0 | – |
| 4 | 5·4 | 11·3 | 18·0 | 24·6 |

TABLE 7

Numbers of Smolts Tagged

| Trap | Year | No. Tagged | Percentage of Run | Tag(s) used[a] |
|---|---|---|---|---|
| Meig | 1957 | 2,918 | 20·9 | Telcothene sleeving |
| | 1958 | 2,688 | 30·2 | Bead |
| | 1959 | 3,490 | 33·7 | Telcothene sleeving, Swedish, Ivorine |
| | 1960 | 2,000 | 27·7 | Bead, Telcothene sleeving |
| Luichart | 1957 | 222 | 62·7 | Telcothene sleeving |
| | 1958 | 863 | 44·3 | Bead |
| | 1959 | 512 | 15·6 | Telcothene sleeving, Swedish |
| | 1960 | 267 | 26·7 | Swedish |

[a] The Telcothene sleeving tag consists of lengths of coloured plastic tubing threaded on to silver wire.
Bead tags consist of small, coloured embroidery beads threaded on the silver wire.
Swedish tags (kindly supplied by Dr. B. Carlin) consist of a plastic-covered paper label, attached by means of a bridle to two wires for insertion into the fish.
Ivorine tags (kindly supplied by the Ministry of Agriculture, Fisheries and Food) consist of a small ivorine disc attached by a wire which is threaded through two holes in the disc.

## TABLE 8

Numbers of Adults caught at the Meig trap

| 1957 Wk. Ending | No. | 1958 Wk. Ending | No. | 1959 Wk. Ending | No. | 1960 Wk. Ending | No. |
|---|---|---|---|---|---|---|---|
| May 4 | 0 | May 3 | 0 | May 2 | 0 | May 7 | 0 |
| 11 | 0 | 10 | 0 | 9 | 0 | 14 | 0 |
| 18 | 0 | 17 | 0 | 16 | 0 | 21 | 1 |
| 25 | 0 | 24 | 0 | 23 | 0 | 28 | 0 |
| June 1 | 1 | 31 | 0 | 30 | 0 | June 4 | 3 |
| 8 | 1 | June 7 | 0 | June 6 | 0 | 11 | 1 |
| 15 | 4 | 14 | 0 | 13 | 3 | 18 | 10 |
| 22 | 2 | 21 | 1 | 20 | 1 | 25 | 1 |
| 29 | 5 | 28 | 8 | 27 | 1 | July 2 | 1 |
| July 6 | 5 | July 5 | 11 | July 4 | 0 | 9 | 0 |
| 13 | 36 | 12 | 15 | 11 | 2 | 16 | 5 |
| 20 | 23 | 19 | 8 | 18 | 23 | 23 | 25 |
| 27 | 39 | 26 | 16 | 25 | 15 | 30 | 22 |
| Aug. 3 | 50 | Aug. 2 | 17 | Aug. 1 | 32 | Aug. 6 | 17 |
| 10 | 69 | 9 | 15 | 8 | 22 | 13 | 54 |
| 17 | 122 | 16 | 33 | 15 | 19 | 20 | 17 |
| 24 | 65 | 23 | 19 | 22 | 25 | 27 | 6 |
| 31 | 31 | 30 | 8 | 29 | 24 | Sept. 3 | 26 |
| Sept. 7 | 65 | Sept. 6 | 4 | Sept. 5 | 36 | 10 | 19 |
| 14 | 41 | 13 | 65 | 12 | 16 | 17 | 5 |
| 21 | 9 | 20 | 10 | 19 | 8 | 24 | 3 |
| 28 | 11 | 27 | 6 | 26 | 13 | Oct. 1 | 1 |
| Oct. 5 | 2 | Oct. 4 | 8 | Oct. 3 | 4 | 8 | 2 |
| 12 | 27 | 11 | 2 | 10 | 2 | 15 | 0 |
| 19 | 3 | 18 | 1 | 17 | 0 | 22 | 0 |
| 26 | 1 | 25 | 5 | 24 | 0 | 29 | 1 |
| | | | | 31 | 0 | | |
| Totals | 612 | | 252 | | 246 | | 220 |
| Total Runs[a] | 613 | | 254 | | 246 | | 220 |

[a] See note to Table 2.

TABLE 9

Numbers of Adults caught at the Luichart trap

| 1957 Wk. Ending | No. | 1958 Wk. Ending | No. | 1959 Wk. Ending | No. | 1960 Wk. Ending | No. |
|---|---|---|---|---|---|---|---|
| May 4 | 0 | May 3 | 0 | May 2 | 0 | May 7 | 0 |
| 11 | 0 | 10 | 0 | 9 | 0 | 14 | 0 |
| 18 | 0 | 17 | 0 | 16 | 0 | 21 | 0 |
| 25 | 0 | 24 | 0 | 23 | 0 | 28 | 0 |
| June 1 | 0 | 31 | 0 | 30 | 0 | June 4 | 0 |
| 8 | 0 | June 7 | 0 | June 6 | 0 | 11 | 3 |
| 15 | 0 | 14 | 0 | 13 | 0 | 18 | 3 |
| 22 | 0 | 21 | 0 | 20 | 0 | 25 | 2 |
| 29 | 0 | 28 | 0 | 27 | 0 | July 2 | 0 |
| July 6 | 0 | July 5 | 0 | July 4 | 5 | 9 | 2 |
| 13 | 6 | 12 | 4 | 11 | 3 | 16 | 0 |
| 20 | 2 | 19 | 0 | 18 | 8 | 23 | 14 |
| 27 | 10 | 26 | 1 | 25 | 18 | 30 | 12 |
| Aug. 3 | 11 | Aug. 2 | 6 | Aug. 1 | 13 | Aug. 6 | 29 |
| 10 | 1 | 9 | 3 | 8 | 13 | 13 | 18 |
| 17 | 20 | 16 | 10 | 15 | 13 | 20 | 40 |
| 24 | 6 | 23 | 3 | 22 | 35 | 27 | 57 |
| 31 | 15 | 30 | 7 | 29 | 53 | Sept. 3 | 20 |
| Sept. 7 | 3 | Sept. 6 | 2 | Sept. 5 | 12 | 10 | 26 |
| 14 | 19 | 13 | 14 | 12 | 2 | 17 | 19 |
| 21 | 5 | 20 | 1 | 19 | 4 | 24 | 3 |
| 28 | 0 | 27 | 14 | 26 | 5 | Oct. 1 | 3 |
| Oct. 5 | 0 | Oct. 4 | 1 | Oct. 3 | 13 | 8 | 7 |
| 12 | 8 | 11 | 3 | 10 | 0 | 15 | 6 |
| 19 | 0 | 18 | 2 | 17 | 0 | 22 | 1 |
| 26 | 8 | 25 | 1 | 24 | 39 | 29 | 9 |
| | | | | 31 | 23 | | |
| Totals | 114 | | 72 | | 259 | | 274 |
| Total Runs[a] | 129 | | 72 | | 269 | | 289 |

[a] See note to Table 2.

TABLE 10

Sex Ratios of Adults caught at the Meig and Luichart traps

| Year | Sex Ratio (Male: Female) | |
|---|---|---|
| | Meig | Luichart |
| 1957 | 1 : 0·81 | 1 : 0·86 |
| 1958 | 1 : 0·81 | 1 : 0·66 |
| 1959 | 1 : 0·65 | 1 : 0·58 |
| 1960 | 1 : 1·52 | 1 : 1·14 |

TABLE 11

Effects of Artificial Freshets at Meig trap, August 1958

| Flow (cusecs) | Period From | To | hrs | No. of fish in trap |
|---|---|---|---|---|
| 37 | 17-viii, 0930 | 18-viii, 0930 | 24 | 4 |
| 49 | 18-viii, 0930 | 18-viii, 2130 | 12 | 6 |
| 61 | 18-viii, 2130 | 19-viii, 0930 | 12 | 0 |
| 73 | 19-viii, 0930 | 19-viii, 2130 | 12 | 1 |
| 121 | 19-viii, 2130 | 20-viii, 2130 | 24 | 1 |
| 73 | 20-viii, 2130 | 21-viii, 0930 | 12 | 1 |
| 61 | 21-viii, 0930 | 21-viii, 2130 | 12 | 2 |
| 49 | 21-viii, 2130 | 22-viii, 0930 | 12 | 1 |
| 37 | 22-viii, 0930 | 22-viii, 2130 | 12 | 1 |

TABLE 12

Recaptures of Tagged Smolts

| Trap | Year Tagged | No. Tagged | No. Recaptured 1958 | 1959 | 1960 | 1961 | 1962 | Percentage Recapture | Site of Recapture Trap | Elsewhere |
|---|---|---|---|---|---|---|---|---|---|---|
| Meig | 1957 | 2,918 | 2 | 1 | 0 | 0 | 0 | 0·1 ( 3) | 2 | 1[a] |
| | 1958 | 2,688 | – | 11 | 1 | 0 | 0 | 0·4 (12) | 11 | 1[b] |
| | 1959 | 3,490 | – | – | 13 | 1 | 0 | 0·4 (14) | 10 | 4[c] |
| | 1960 | 2,000 | – | – | – | 1 | 1 | 0·1 ( 2) | 0 | 2[d] |
| Luichart | 1957 | 322 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1958 | 863 | – | 5 | 0 | 0 | 0 | 0·6 ( 5) | 0 | 5[e] |
| | 1959 | 512 | – | – | 3 | 0 | 0 | 0·6 ( 3) | 1 | 2[b] |
| | 1960 | 267 | – | – | – | 2 | 1 | 1·1 ( 3) | 0 | 3[f] |

Figures in brackets indicate total number recaptured

[a] River Conon above Loch Achonachie (rod-caught)

[b] Conon estuary (sweep net)

[c] Three recaptured in the Conon estuary (sweep net) and one in the River Conon above Loch Achonachie (rod caught)

[d] One recaptured in drift nets off More Head and one in the River Conon below Loch Achonachie (rod caught)

[e] Three recaptured in the Conon estuary (sweep net) and two in the Meig trap

[f] One recaptured in drift nets off Gourdon, one from bag nets at Balintore and one in the Meig trap.

TABLE 13

Captures of Kelts at the Meig trap

| Month | 1957-58 | 1958-59 | 1959-60 |
|---|---|---|---|
| November | 23 | 0 | 2 |
| December | 11 | 7 | 20 |
| January | 3 | 2 | 0 |
| February | 2 | 0 | 0 |
| March | 3 | 0 | 0 |
| April | 57 | 2 | 3 |
| May | 45 | 9 | 0 |
| June | 7 | 6 | 0 |
| July | 0 | 2 | 0 |
| August | 0 | 0 | 0 |
| September | 0 | 0 | 0 |
| October | 0 | 0 | 0 |
| | 151 (24·6) | 28 (10·9) | 25 (10·2) |

Figures in brackets indicate percentage of corresponding upstream run.

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